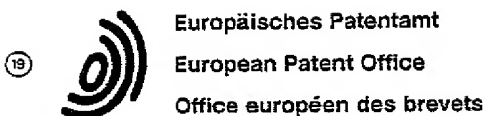


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(54) Phosphate-coated electroluminescent phosphor for electroluminescent lamp and a process for producing the same.

(57) Phosphors are dispersed in an aqueous solution containing phosphate ions and alkali metal ions and/or ammonium ions; while maintaining the pH value of the resulting slurry at 4 or more, an aqueous solution of a salt of at least one metal selected from the group consisting of magnesium, calcium, strontium and barium is added to the above slurry; the phosphors are coated with the metal phosphates the coated phosphors are then taken by filtration from the reaction mixture, washed with water and calcined to obtain phosphate-coated electroluminescent phosphors for electroluminescent lamps.

The phosphate-coated electroluminescent phosphor of the present invention for electroluminescent lamp has a higher moisture resistance and a longer life than known phosphors. The phosphor is applicable to back light for word processors, a panel light for air crafts, a panel light for interior use in automobiles, weather proofing panel light for exterior use in automobiles, etc.

EP 0 333 053 A2

# PHOSPHATE-COATED ELECTROLUMINESCENT PHOSPHOR FOR ELECTROLUMINESCENT LAMP AND A PROCESS FOR PRODUCING THE SAME

The present invention relates to a phosphate-coated electroluminescent phosphor for ac powder electroluminescent lamps (hereafter referred to as "EL lamp") and a process for producing the same.

More particularly, the present invention relates to a phosphate-coated electroluminescent phosphor for EL lamps having an improved moisture resistance and a long life, obtained by coating a phosphor with specific phosphates, and to a process for producing the same.

In recent years, EL lamps mainly using zinc sulfide as a phosphor have been recommended as a back light for display equipments since they have such merits that they exhibit a uniform luminance over a wide area and they are lightweighted.

However, such phosphors encounter such demerits that they are so sensitive to humidity that their luminance rapidly decreases by the moisture coming from the outside.

Therefore, conventionally used electroluminescent phosphors are designed to provide on a back electrode an insulating layer, a phosphor layer composed of a mixture of an organic binder having a high dielectric constant and a phosphor such as zinc sulfide, etc. and a transparent electrode layer, and the whole system being covered with a moisture-proofing film so as to prevent the penetration of moisture. However, the surface of the phosphor layer is gradually blackened and deteriorated to cause reduction of luminance, when exposed to high humidity over a long period of time.

This tendency is particularly remarkable under irradiation with UV rays, resulting in marked reduction in life of EL lamps.

In order to eliminate such shortcomings, it has been proposed to cover the phosphor with a variety of moisture-proofing materials, whereby moisture resistance is imparted to the phosphor to prolong its life.

For example, JP-A-58-150294 teaches that a life of phosphor powders can be prolonged by coating the powders with a dense insulating material such as silicon nitride, silicon oxide, yttrium oxide, barium titanate, etc. so as to prevent invasion of water molecules or various ions from the outside into the phosphor.

Further, JP-B-60-14054 discloses that waterproofing property and chemical stability of the phosphor can be improved by taking a three-layered structure comprising, in succession, an alkaline earth chalcogenide phosphor having been provided on the surface thereof a layer of an oxide of an alkaline earth metal and a moisture resistant oxide layer in contact with the alkaline earth metal oxide. Furthermore, USP 4,181,753 describes a zinc phosphate-coated phosphor by the reaction of a zinc sulfide phosphor itself with phosphoric acid, which EL lamp has an impermeable insulating property.

However, even these improved methods fail to provide phosphors satisfying the life required for commercial products (for example, the luminance of the lighted phosphor should not decrease to less than 10 nt even after 1500 hours).

According to the present invention, there are provided a phosphate-coated electroluminescent phosphor for EL lamp comprising a phosphor coated with a phosphate of at least one metal selected from the group consisting of magnesium, calcium, strontium and barium, and a process for producing a phosphor for EL lamp coated with a phosphate of at least one metal selected from the group consisting of magnesium, calcium, strontium and barium, which comprises dispersing a phosphor in an aqueous solution containing phosphate ions and alkali metal ions and/or ammonium ions, adding an aqueous solution of a salt of at least one metal selected from the group consisting of magnesium, calcium, strontium and barium to the resulting slurry while maintaining the pH value of the resulting mixture at 4 or more, coating the metal phosphate on the phosphor, then filtering off the coated phosphor from the mixture, washing the coated phosphor with water and then calcining the coated phosphor.

In the present invention, the phosphate used to cover the phosphor for EL lamps refers to a phosphate of at least one metal selected from the group consisting of magnesium, calcium, strontium and barium, composite phosphates or condensed phosphates thereof and/or mixed phosphates.

More specifically, the phosphate are, for example, magnesium phosphate, magnesium hydrogen-phosphate, calcium phosphate, calcium hydrogenphosphate, barium phosphate, strontium phosphate, magnesium pyrophosphate, calcium pyrophosphate, strontium pyrophosphate, barium pyrophosphate, calcium magnesium phosphate, strontium magnesium phosphate, barium magnesium phosphate, calcium magnesium pyrophosphate, strontium magnesium pyrophosphate, barium magnesium pyrophosphate, strontium calcium magnesium phosphate, barium calcium magnesium phosphate, strontium calcium magnesium pyrophosphate, barium calcium magnesium pyrophosphate, barium strontium calcium magnesium phosphate, barium strontium calcium magnesium pyrophosphate, strontium calcium phosphate, barium calcium phosphate, strontium calcium pyrophosphate, barium calcium pyrophosphate, barium strontium calcium

phosphate, barium strontium calcium pyrophosphate, etc.; or composite phosphates or condensed phosphates thereof and/or mixed phosphates. Of these, preferred are calcium magnesium phosphate, magnesium phosphate, magnesium hydrogenphosphate, calcium phosphate, strontium phosphate, barium phosphate, strontium magnesium phosphate, barium magnesium phosphate, strontium calcium magnesium phosphate, barium calcium magnesium phosphate and barium strontium calcium magnesium phosphate.

In general, electroluminescent phosphors used for EL lamps have a variety of mean particle diameters and, as a matter of course, have a variety of size distributions. Therefore, in the case of coating the phosphors with these phosphates, it is impossible to adhere onto the respective phosphor particles in a uniform layer thickness by a method which comprises coating the phosphates onto the surface of phosphor in a slurry. However, the coated amount of the phosphate onto the phosphor can be expressed in terms of the quantity of phosphate. In the case where the mean particle diameter of the phosphor is about 30  $\mu\text{m}$  and the metal phosphate is magnesium phosphate, for example, the coating amount ratio of magnesium phosphate to the phosphor is generally about 0.05 : 100 to about 13 : 100, preferably about 0.1 : 100 to about 10 : 100. In the case where the mean particle diameter is about 3  $\mu\text{m}$ , the ratio is generally about 0.5 : 100 to about 130 : 100, preferably about 1 : 100 to about 100 : 100. Further, in the case where the mean particle diameter of the phosphor is about 10  $\mu\text{m}$ , the ratio is generally about 0.15 : 100 to about 40 : 100, preferably about 0.3 : 100 to about 30 : 100. Furthermore, in the case where the mean particle diameter of the phosphor is about 60  $\mu\text{m}$ , the ratio is generally in the range of about 0.025 : 100 to about 6.5 : 100, preferably about 0.05 : 100 to about 5 : 100.

Thus, the coating amount ratio of the metal phosphate to the phosphor depends on the mean particle diameter of the phosphor to be coated. However, in the case a commercially available phosphor is used, it is recommended to coat the phosphor in the amount range satisfying the inequality:

$$0.007 \cdot \frac{d}{D_{50}} \cdot W_P \leq W_C \leq 1.5 \cdot \frac{d}{D_{50}} \cdot W_P$$

wherein  $W_C$  represents the weight of coating metal phosphate (g),  $d$  the density of coating metal phosphate ( $\text{g}/\text{cm}^3$ ),  $D_{50}$  the mean particle diameter of the phosphor and  $W_P$  the weight of phosphor (g), preferably,

$$0.015 \cdot \frac{d}{D_{50}} \cdot W_P \leq W_C \leq 1.2 \cdot \frac{d}{D_{50}} \cdot W_P$$

wherein  $W_C$ ,  $d$ ,  $D_{50}$  and  $W_P$  represent the same meanings as defined above.

The thickness of the layer coated onto the phosphor in the above coating amounts cannot be primarily determined since the phosphor has a size distribution as described above. However, when the mean particle diameter of the phosphor falls in the range from about 3 to about 60  $\mu\text{m}$ , the layer thickness is generally about 0.005  $\mu\text{m}$  to about 1  $\mu\text{m}$ , preferably about 0.01  $\mu\text{m}$  to about 0.8  $\mu\text{m}$ . On the phosphor having a mean particle diameter in the above range, the metal phosphate may be coated so as to have a thickness of the layer of the metal phosphate falling in the above-mentioned range.

In the present invention, the coating amount is not critical. However, in the case the coating amount is less than the lower limit described above, the effect of improving the moisture resistance of the phosphor may be poor. On the other hand, as the amount of the coated phosphate becomes large, the moisture resistance is improved but the luminance is reduced. Therefore, it is preferred that the coating amount be in the range described above.

In the present invention, the phosphate-coated phosphor for EL lamp is obtained by dispersing an electroluminescent phosphor in an aqueous solution containing phosphate ions and alkali metal ions and/or ammonium ions (hereafter referred to as phosphate-supplying aqueous solution), adding an aqueous solution of the metal salt to the resulting slurry, while maintaining the pH value of the resulting mixture at 4 or more, coating the metal phosphate on the phosphor, then filtering off the coated phosphor from the mixture, washing the coated phosphor with water and then calcining the coated phosphor.

The phosphate-supplying aqueous solution may be prepared by dissolving one or more alkali metal phosphates or ammonium phosphates in water, or by mixing an aqueous solution containing phosphate ions, an aqueous solution containing alkali metal ions and/or an aqueous solution containing ammonium

ions. As the phosphate-supplying aqueous solution, there can be used aqueous solutions of alkali phosphates such as tripotassium phosphate, dipotassium phosphate, monopotassium phosphate, trisodium phosphate, disodium phosphate, monosodium phosphate, etc.; ammonium phosphates such as triammonium phosphate, diammonium phosphate, monoammonium phosphate, etc.; magnesium phosphate, phosphoric acid or the like.

As the alkali metal ion source, there can be used aqueous solutions of potassium hydroxide or sodium hydroxide; as the ammonium ion source, ammonia water and the like can be used. In the case that necessary amounts of the alkali metal ions or ammonium ions has already been present in the aqueous solution containing phosphate ions, of course, it is unnecessary to further add an alkali metal ions aqueous solution or an aqueous solution containing ammonium ions.

The phosphate ion concentration in the phosphatesupplying aqueous solution is not critical but generally in the range of about 0.01 to about 5% by weight, preferably about 0.03 to 1% by weight, when calculated as  $H_3PO_4$ .

The alkali metal ion and/or ammonium ion concentration in the phosphate-supplying aqueous solution is not critical but generally in the range of about 5 to 500 mmol/l, preferably about 10 to 200 mmol/l.

The starting metal salts include chlorides and nitrates of magnesium, calcium, strontium and barium; water soluble inorganic acid salts such as magnesium sulfate, etc.; and water soluble organic acid salts such as acetates of the metals described above. Specific examples thereof are chlorides such as magnesium chloride, calcium chloride, strontium chloride and barium chloride, etc.; nitrates such as magnesium nitrate, calcium nitrate, strontium nitrate and barium nitrate, etc.; sulfates such as magnesium sulfate, etc.; acetates such as magnesium acetate, calcium acetate, strontium acetate, barium acetate, etc.

The above inorganic acid salt and organic acid salt may be used alone or in combination of two or more.

The metal ion concentration in the metal salt aqueous solution is not critical but generally in the range of about 0.01 to about 10% by weight, preferably about 0.05 to about 5% by weight.

In general, once the metal salt aqueous solution is added to the slurry containing the phosphor in phosphate-supplying aqueous solution, the reaction immediately occurs and forms a coating onto the phosphor. Accordingly, the amounts of the starting materials added are almost identical with the coating amount in many cases. However, it is recommended to previously evaluate the amount of the phosphate coated on the phosphor in a prescribed composition of the starting materials, by a simple preliminary experiment, prior to the reaction.

In the process of the present invention, the alkali metal ions and/or ammonium ions present in the phosphate-supplying aqueous solution are required to be used in stoichiometrical amounts sufficient to neutralize free acids formed from the starting metal salts, which acid is by-produced in the reaction of the phosphate ion-containing aqueous solution and the metal salt aqueous solution. A pH value of the phosphor-dispersed slurry has been previously adjusted to about 4 to about 10.

In the case the amount of alkali metal ions and/or ammonium ions necessary for neutralizing the free acids by-produced is insufficient, the phosphate is coated onto the phosphor in a low yield and the remaining free acids react further with the phosphor to by-produce hydrogen sulfide. As the result, no uniform phosphate coating onto the surface of the phosphor can be obtained.

On the other hand, where the alkali metal ions and/or ammonium ions are excessively present in the reaction mixture after the reaction has been completed, the phosphate formed by the reaction is hardly coated onto the surface of the phosphor and is released into the aqueous solution or the phosphate deposits on the surface of the phosphor as phosphate masses. In this case, the effect of improving the moisture resistance of the resulting phosphor becomes poor and its luminance decreases, which are not desired.

In the present invention, the process is carried out with preventing the reaction mixture from becoming strongly acidic (pH of less than about 4) during the reaction progress (from initiation to completion, of the reaction) between the phosphate-supply aqueous solution and the metal salt aqueous solution. In general, there can be utilized a method in which an equimolar amount of the alkali metal ions and/or ammonium ions have previously been allowed to be present in the slurry prior to the reaction or a method in which an aqueous solution containing the alkali metal ions and/or ammonium ions is added to the reaction mixture while monitoring the pH of the mixture during the reaction thereby to control the pH value, or the like. When the pH of the reaction mixture after completion of the reaction is generally larger than 4 or more, it can be regarded that the pH would be kept at about 4 or more also during the reaction. In order to effect the coating uniformly in a good yield, it is desirable to incorporate the alkali metal ions and/or ammonium ions co-existing with the phosphate ions, in such a way that the pH of the reaction mixture during the course of the reaction falls in the range of about 4 to about 10, preferably about 5 to about 8, more preferably about 6

to about 7.

The amount of the electroluminescent phosphor to be dispersed in the phosphate-supplying aqueous solution is not critical. However, it is generally in the range of about 1 to about 40% by weight, preferably about 1 to about 30% by weight, based on the aqueous solution.

5 The lesser the amount of the phosphor dispersed in the aqueous solution is, more uniformly can the phosphate be coated onto the phosphor surface and the resulting phosphate-coated phosphor can exhibit more improved moisture resistance.

When the amount of the phosphor added to the aqueous solution exceeds about 40% by weight, it tends to be difficult to form a uniform dispersion. For this reason, uniform coating of the formed phosphate  
10 onto the phosphor surface tends to be difficult.

A method, device and conditions for uniformly dispersing the phosphor in the aqueous solution may vary since the dispersion state depends upon shape of a container, shape of an agitation blade, an agitation rate, particle diameter of the electroluminescent phosphor and size distribution, etc. Known stirring machines and agitation techniques may be appropriately chosen in such a manner that a good and uniform  
15 dispersion is obtained throughout the whole procedures from the onset of the reaction to the cooling treatment.

The amount of the starting metal salt aqueous solution to be incorporated into the phosphate-supplying aqueous solution is about 5 to about 100 parts by volume, preferably about 7 to about 20 parts by volume, per 100 parts by volume of the phosphate-supplying aqueous solution. In this case, the phosphate  
20 concentration in the phosphate-supplying aqueous solution falls in the range of about 0.01 to about 5% by weight, when calculated as  $H_3PO_4$ , and the metal salt concentration in the starting metal salt aqueous solution ranges from about 0.01 to 10% by weight, when calculated as metal salt ignoring crystal water. The amounts used and concentrations of these aqueous solutions may be determined within the above-described ranges in view of the intended amount of metal phosphate coating on the phosphor.

25 As the concentration of the phosphate formed by the reaction between the phosphate-supplying aqueous solution and the metal salt aqueous solution becomes lower, the formed phosphate can uniformly cover the phosphor surface and this is recommended.

However, even in the case of incorporating the aqueous solution containing a necessary amount of the metal salt in a high concentration, the limit is about 5 parts by volume. With a higher concentration and a  
30 smaller volume, the formed phosphate tends to form agglomerated particles, so that the phosphate is released into the aqueous solution or deposits on the surface of the phosphor as phosphate masses. As a result, the effect of improving the moisture resistance of the resulting phosphor becomes poor and its luminance decreases, which are not desired.

On the other hand, in the case the aqueous solution containing a necessary amount of the metal salt is  
35 incorporated in a larger volume than 100 parts by volume, such a manner of addition is not only useless but also a waste of labor since the improvement in uniform coating hits the ceiling as compared with a more moderate addition.

The reaction is initiated by adding the metal salt aqueous solution to the slurry of the phosphor in the phosphate-supplying aqueous solution.

40 It is recommended to slowly add the metal salt aqueous solution to the phosphate-supplying aqueous solution, intending to uniformly disperse the metal phosphate formed in the slurry. Although the rate of the addition depends upon the properties of the materials used, it cannot be easily determined. However, for example, about 5 parts by volume of the metal salt aqueous solution may be added to 100 parts by volume of the phosphate-supplying aqueous solution, in which the phosphor has been dispersed, generally over 10  
45 minutes or longer. Such a manner of addition is desirable because, as the addition takes a longer period of time, the formed phosphate can cover the phosphor more uniformly.

The reaction temperature is not critical but usually ranges from room temperature to about 80°C, preferably from room temperature to about 60°C. In general, the reaction proceeds sufficiently at room temperature; however it is also possible to carry out the reaction by heating the aqueous solution at a  
50 temperature between a temperature higher than room temperature and a temperature around which steam bubbles begin to appear in the aqueous phase.

The mixture to which the metal salt aqueous solution has been added can be subsequently subjected to heat treatment at a temperature from a temperature higher than the reaction temperature to about 100°C, preferably from about 80 to about 100°C, for about 0.5 to about 3 hours.

55 The heat treatment may serve to complete the deposition and coating of the phosphate formed by the reaction onto the phosphor and at the same time, may serve to aging, whereby the phosphate is coated onto the phosphor more smoothly and more uniformly.

While maintaining the dispersion of the whole particles, the heat treatment may follow cooling of the

reaction mixture; the mixture is then filtered and washed with water in a conventional manner.

The phosphor after the filtration and rinsing is then dried at room temperature to about 150 °C, by appropriately choosing the drying method from air-drying, hot air-drying, vacuum-drying, etc. The phosphor is further calcined to form a denser phosphate layer thereon.

5 It is desired that the calcination be conducted at a high temperature not causing reduction of a luminance of the phosphor. The phosphate-coated phosphor for EL lamp according to the present invention transits from an amorphous state to a crystalline state at about 600 ° to about 700 °C. Therefore, the maximum temperature of the calcination is set within the temperature range up to this phase transition point, generally about 150 ° to about 300 °C. The calcination is carried out within the temperature range for  
10 about 0.5 to about 2 hours. The calcination may be carried out in the air or in an inert gas such as nitrogen, argon, etc.

Further, in order to obtain the denser phosphate layer with minimized defects, it is, of course, possible to repeatedly conduct the coating. In this case, the moisture resistance can further be improved.

15 In practice of the present invention, it is also possible to coat or use iron phosphates, manganese phosphate, chromium phosphate, cerium phosphate, zinc phosphate, etc. as coloring pigments and/or ultraviolet absorbers within a range not lowering the moisture resistance.

The phosphate-coated phosphor for EL lamp of the present invention has a higher moisture resistance than the conventional phosphors. Therefore, the phosphor of the present invention is applicable, as a long-life EL lamp, to back light for word processors, a panel light for air crafts, a panel light for interior use in  
20 automobiles, weather proofing panel light for exterior use in automobiles, all purpose use as panel light and hence, the industrial value is extremely great.

The following examples serve to give specific illustrations of the practice of the present invention but they are not intended in any way to limit the scope of the present invention.

25 The moisture resistance test and blackening resistance test used in the examples and comparative examples were carried out in the following manner.

#### Moisture resistance test:

30 The EL lamp was kept in a thermostat at a temperature of 65 °C under a humidity of 95% RH for 100 hours. The lamp was then continuously lighted by driving at 115 V and 400 Hz at 23 °C, 40-60% RH. Its initial luminance [nt], half life [hr] and 10 nt life [hr] (time until the luminance reaches 10 nt) were determined.

#### 35 Blackening resistance test:

0.200 Gram of the electroluminescent phosphor sample, 0.100 g of castor oil and 13  $\mu$ l of 23% by volume water-ethanol solution were kneaded. A light was allowed to emit for 30 minutes by driving at 200 V  
40 and 400 Hz under irradiation from a UV lamp named UVL-56, in a light emission cell having a thickness of 50  $\mu$ m.

Thereafter, blackening change of the phosphor particles was examined. A blackened sample was expressed by x and a non-blackened sample by o.

45 In the examples, parts are all by weight unless otherwise indicated.

#### Example 1

50 0.71 Gram of triammonium phosphate trihydrate, was dissolved in 600 ml of ion-exchanged water. The solution was charged together with 100 g of a commercially available zinc sulfide type electroluminescent phosphor (mean particle diameter of 30  $\mu$ m) in a 1-liter separable flask and stirred to disperse the phosphor with a paddle agitation blade. The slurry had a pH of about 9.

55 Thereto were carefully added 75 ml of a solution of 0.53 g of magnesium chloride hexahydrate and 0.39 g of calcium chloride dihydrate in ion-exchanged water over 45 minutes (reaction temperature : about 20 ° - 40 °C). Then, the mixture was heated to 90 ° to 100 °C and refluxed for an hour.

With continuing the agitation, the reaction mixture was cooled; at this time, the pH was about 6.

The resulting phosphate-coated electroluminescent phosphor was subjected to solid-liquid separation. Then, the phosphor was washed with 1 liter of ion-exchanged water, dried at a temperature of 130 °C for an

hour and ground.

Then, the phosphor was calcined at a temperature of 150° C for an hour and further at a temperature of 250° C for an hour. Thus, a calcium magnesium phosphate-coated (0.45 part per 100 parts of the phosphor) electroluminescent phosphor was obtained.

5 The coating treatment described above was further repeated on the thus obtained phosphor once again to give a calcium magnesium phosphate-coated (0.9 part per 100 parts of the phosphor) electroluminescent phosphor (two-layer coating).

Subsequently, an insulating layer of a composition composed of BaTiO<sub>3</sub> and a cellulosic resin having a high dielectric constant was formed on an aluminum thin plate as a back electrode. A mixture of 15 parts of a cellulosic resin having a high dielectric constant (dielectric constant of 18), 45 parts of dimethylformamide and 40 parts of the calcium magnesium phosphate-coated phosphor described above was coated on the insulating layer by the doctor blade method. Thereafter, the system was dried by heating at a temperature of 130° C for 10 minutes to obtain a phosphor layer having a thickness of 50 μm. For moisture-proofing, the whole system was further covered with a polychlorotrifluoroethylene film.

15 With respect to the thus obtained EL lamp, the moisture resistance test of the EL lamp and blackening resistance test of the phosphate-coated electroluminescent phosphor were conducted. The results are shown in Table 1.

## 20 Example 2

Triammonium phosphate trihydrate, 0.77 g, was dissolved in 600 ml of ion-exchanged water and the resulting solution was charged in a 1-liter separable flask together with 100 g of the same electroluminescent phosphor as used in Example 1 and stirred to disperse the phosphor with a paddle agitation blade. The slurry had a pH of about 9.

There to were carefully added 75 ml of a solution of 1.16 g of magnesium chloride hexahydrate in ion-exchanged water over 45 minutes (reaction temperature : about 20° - 40° C). Then, the mixture was heated to 90° to 100° C and refluxed for an hour.

With continuing the agitation, the reaction slurry was cooled; at this time, the pH was about 7.

30 Subsequently, the same procedure as in the former stage in Example 1 was repeated (two-layer coatings) to give a magnesium phosphate-coated (0.8 part per 100 parts of the phosphor) electroluminescent phosphor.

The moisture resistance test of the EL lamp obtained in the same manner as in Example 1 from this phosphate-coated electroluminescent phosphor and blackening resistance test of the phosphate-coated electroluminescent phosphor were performed. The results are shown in Table 1.

## Example 3

40 Triammonium phosphate trihydrate, 1.43 g, was dissolved in 600 ml of ion-exchanged water and the solution was charged in a 1-liter separable flask together with 100 g of the same electroluminescent phosphor as used in Example 1 and stirred to disperse the phosphor with a paddle agitation blade. The slurry had a pH of 9.

There to were carefully added 75 ml of a solution of 1.06 g of magnesium chloride hexahydrate and 0.77 g of calcium chloride dihydrate in ion-exchanged water over 45 minutes (reaction temperature: about 20° - 40° C). Then, the mixture was heated to 90° to 100° C and refluxed for an hour.

With continuing the agitation, the reaction mixture was cooled; at this time, the pH was about 6.

Subsequently, the same procedure as the former stage in Example 1 was carried out (one-layer coating) to give a calcium magnesium phosphate-coated (0.9 part per 100 parts of the phosphor) electroluminescent phosphor.

The moisture resistance test of the EL lamp obtained in the same manner as in Example 1 from this phosphate-coated electroluminescent phosphor and blackening resistance test of the phosphate-coated electroluminescent phosphor were performed. The results are shown in Table 1.

55

## Example 4

Triammonium phosphate trihydrate, 1.55 g, was dissolved in 600 ml of ion exchange water and the

solution was charged in a 1-liter separable flask together with 100 g of the same electroluminescent phosphor as used in Example 1 and stirred to disperse the phosphor with a paddle agitation blade. The slurry had a pH of about 9.

Thereto were carefully added 75 ml of a solution of 2.32 g of magnesium chloride hexahydrate in ion-exchanged water over 45 minutes (reaction temperature : 20° - 40° C). Then, the mixture was heated to 90° to 100° C and refluxed for an hour.

With continuing the agitation, the reaction mixture was cooled; at this time, the pH was about 7.

Subsequently, the same procedure as in the former stage in Example 1 was carried out (one-layer coating) to give a magnesium phosphate-coated (0.8 part per 100 parts of the phosphor) electroluminescent phosphor.

The moisture resistance test of the EL lamp obtained in the same manner as in Example 1 from this phosphate-coated electroluminescent phosphor and blackening resistance test of the phosphate-coated electroluminescent phosphor were performed. The results are shown in Table 1.

#### Example 5

1 mol/l Phosphoric acid aqueous solution, 7.62 ml, and 22.8 ml of 1 mol/l potassium hydroxide aqueous solution were diluted with ion-exchanged water to make the whole volume 600 ml. The diluted solution was charged in a 1-liter separable flask together with 100 g of the same electroluminescent phosphor as used in Example 1 and stirred to disperse the phosphor with a paddle agitation blade. The slurry had a pH of about 9.

Thereto were carefully added 75 ml of an aqueous solution of 2.45 g of magnesium acetate tetrahydrate over 45 minutes (reaction temperature : 25° - 50° C). Then, the mixture was heated to 90° to 100° C and refluxed for an hour.

With continuing the agitation, the reaction slurry was cooled; at this time, the pH was about 7.

Hereafter, the same procedure as in Example 1 was repeated (two-layer coating) to give a phosphate-coated (1.6 parts per 100 parts of the phosphor) electroluminescent phosphor.

The moisture resistance test of the EL lamp obtained in the same manner as in Example 1 from this phosphate-coated electroluminescent phosphor and blackening resistance test of the phosphate-coated electroluminescent phosphor were performed. The results are shown in Table 1.

#### Example 6

1 mol/l Phosphoric acid aqueous solution, 19.0 ml, and 57 ml of 1 mol/l ammonia aqueous solution were diluted with ion-exchanged water to make the whole volume 600 ml. The diluted solution was charged in a 1-liter separable flask together with 100 g of the same electroluminescent phosphor as used in Example 1 and stirred to disperse the phosphor with a paddle agitation blade. The slurry had a pH of about 9.

Thereto were carefully added 75 ml of an aqueous solution of 5.80 g of magnesium chloride hexahydrate in ion-exchanged water over 45 minutes (reaction temperature : 20° - 50° C). Then, the mixture was heated to 90° to 100° C and refluxed for an hour.

With continuing the agitation, the reaction mixture was cooled; at this time, the pH was about 7.

Subsequently, the same procedure as in Example 1 was repeated (two-layer coating) to give a phosphate-coated (4.8 parts per 100 parts of the phosphor) electroluminescent phosphor.

The moisture resistance test of the EL lamp obtained in the same manner as in Example 1 from this phosphate-coated electroluminescent phosphor and blackening resistance test of the phosphate-coated electroluminescent phosphor were performed. The results are shown in Table 1.

#### Example 7

9.63 Grams of monosodium phosphate monohydrate were dissolved in 460 ml of ion-exchanged water. The solution was charged together with 100 g of a commercially available zinc sulfide type electroluminescent phosphor (mean particle diameter of 10  $\mu$ m) in a 1-liter separable flask and stirred to disperse the phosphor with a paddle agitation blade. Then 140 ml of 1 mol/l aqueous ammonia was added thereto to adjust the pH of the slurry to about 10.

Thereto were added 75 ml of a solution of 10.6 g of magnesium chloride hexahydrate and 7.7 g of



calcium chloride dihydrate in ion-exchanged water over 45 minutes (reaction temperature : 20° - 50° C). Thereafter, the mixture was heated to 90° - 100° C and refluxed for an hour.

With continuing the agitation, the reaction mixture was cooled; at this time, the pH was about 7.

Subsequently, the same procedure as in the former stage in Example 1 was repeated (two-layer coatings) to give a calcium magnesium phosphate-coated (20 parts per 100 parts of the phosphor) electroluminescent phosphor.

The moisture resistance test of the EL lamp obtained from the phosphate-coated electroluminescent phosphor and blackening resistance test of the phosphate-coated electroluminescent phosphor were carried out in the same manner as in Example 1. Table 1 shows the results.

#### Example 8

The same procedure (two-layer coatings) as in Example 1 was repeated with the materials shown in Table 1 except that the commercially available zinc sulfide type electroluminescent phosphor was replaced by that having a mean particle diameter of 50  $\mu$ m to obtain a phosphate-coated electroluminescent phosphor shown in Table 1.

With the phosphor, an EL lamp was prepared with the same manner as in Example 1 and the moisture resistance test of the EL lamp was conducted. The blackening resistance test of the phosphate-coated electroluminescent phosphor was also carried out in the same manner as in Example 1. Table 1 shows the results.

#### Examples 9 through 20

The phosphate-coated electroluminescent phosphors shown in Table 1 were prepared according to the same procedure as in Example 1 (the same reaction temperature) with the same commercially available phosphors and the starting materials as shown in Table 1 (two-layer coating).

With the phosphors, EL lamps were prepared with the same manner as in Example 1 and the moisture resistance test of the EL lamps was conducted. The blackening resistance test of the phosphate-coated electroluminescent phosphors was also carried out in the same manner as in Example 1. Table 1 shows the results.

#### Example 21

The same procedure (two-layer coating) as in Example 1 was repeated with the materials shown in Table 1 except that the reaction temperature was 20°-60° C and the heat treatment after the reaction was neglected to obtain a phosphate-coated electroluminescent phosphor.

With the phosphor, an EL lamp was prepared and the moisture resistance test of the EL lamp and the blackening resistance test of the phosphate-coated electroluminescent phosphor were carried out in the same manner as in Example 1. Table 1 shows the results.

#### Comparative Example 1

The moisture resistance test of the EL lamp obtained by using the same commercially available zinc sulfide type electroluminescent phosphor as in Example 1 itself and the blackening resistance test of the electroluminescent phosphor were performed. The results are shown in Table 1.

#### Comparative Example 2

The same commercially available zinc sulfide type electroluminescent phosphor, 100 g, as used in Example 1 were charged in a 1-liter separable flask together with 600 ml of ion-exchanged water and stirred to disperse the phosphor with a paddle agitation blade. Thereinto were carefully added 0.60 g of 86% by weight phosphoric acid aqueous solution. The slurry had a pH of about 2. Then, the mixture was heated to 90° to 100° C and gently refluxed for an hour. At this stage, hydrogen sulfide gas evolved.

With continuing the agitation, the reaction slurry was cooled; at this time, the pH was about 3.

Subsequently, the same procedure as the former stage in Example 1 was repeated to give a phosphate-coated (zinc phosphate, about 0.7 part per 100 parts of the phosphor) electroluminescent phosphor.

5 The moisture resistance test of the EL lamp with this phosphate-coated electroluminescent phosphor and blackening resistance test of the phosphate-coated electroluminescent phosphor were performed in the same manner as in Example 1.

The results are shown in Table 1.

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#### Comparative Example 3

The same commercially available zinc sulfide type electroluminescent phosphor, 20 g, as used in Example 1 were stirred and treated for an hour in 100 ml of isopropanol solution of tetraisopropoxytitanium and diisopropoxybarium (10% by weight as  $\text{BaTiO}_3$ ) followed by filtering and air-drying. The phosphor was  
15 calcined in the air at a temperature of  $150^\circ\text{C}$  for an hour and then at  $250^\circ\text{C}$  for an hour to give a barium titanate-coated electroluminescent phosphor.

The blackening resistance test of the barium titanate-coated electroluminescent phosphor was performed.

20 The results are shown in Table 1.

#### Comparative Example 4

25 With the same commercially available zinc sulfide type electroluminescent phosphor as used in Example 7 (mean particle diameter:  $10\ \mu\text{m}$ ), the moisture resistance test of the EL lamp and the blackening resistance test of the electroluminescent phosphor were carried out in the same manner as in Example 1. Table 1 shows the results.

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#### Comparative Example 5

With the same commercially available zinc sulfide type electroluminescent phosphor as used in Example 8 (mean particle diameter:  $50\ \mu\text{m}$ ), the moisture resistance test of the EL lamp and the blackening  
35 resistance test of the electroluminescent phosphor were carried out in the same manner as in Example 1. Table 1 shows the results.

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Table 1

Example	Source of Phosphate	Metal Salt	pH	
			before reaction	after reaction
1	$(\text{NH}_4)_3\text{PO}_4 \cdot 3\text{H}_2\text{O}$ , 0.71g	$\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$ , 0.53g $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ , 0.39g	9	6
2	$(\text{NH}_4)_3\text{PO}_4 \cdot 3\text{H}_2\text{O}$ , 0.77g	$\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$ , 1.16g	9	7
3	$(\text{NH}_4)_3\text{PO}_4 \cdot 3\text{H}_2\text{O}$ , 1.43g	$\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$ , 1.06g $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ , 0.77g	9	6
4	$(\text{NH}_4)_3\text{PO}_4 \cdot 3\text{H}_2\text{O}$ , 1.55g	$\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$ , 2.32g	9	7
5	$\text{H}_3\text{PO}_4$ , 1M 7.6 ml $\text{KOH}$ , 1M 22.8 ml	$\text{Mg}(\text{OCOCH}_3)_2 \cdot 4\text{H}_2\text{O}$ , 2.45 g	9	7
6	$\text{H}_3\text{PO}_4$ , 1M 19.0 ml $\text{NH}_4\text{OH}$ , 1M 57.0 ml	$\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$ , 5.80g	9	7
7	$\text{NaH}_2\text{PO}_4 \cdot \text{H}_2\text{O}$ , 9.63 g $\text{NH}_4\text{OH}$ , 1M 140 ml	$\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$ , 10.6g $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ , 7.7g	10	7
8	$(\text{NH}_4)_3\text{PO}_4 \cdot 3\text{H}_2\text{O}$ , 0.71g	$\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$ , 0.53g $\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$ , 0.39g	9	6

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Coated Phosphate Amount Species (of phosphor to be coated)	Initial Luminance (nt)	Half Life (hr)	10 nt Life (hr)	Blackening Resistance
Calcium magnesium phosphate	77	110	2300	○
Magnesium phosphate	76	108	2200	○
Calcium magnesium phosphate	80	100	2000	○
Magnesium phosphate	76	105	2000	○
Magnesium phosphate	73	105	2000	○
Magnesium phosphate	60	110	2300	○
Calcium magnesium phosphate	46	115	2400	○
Calcium magnesium phosphate	79	130	3000	○

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19	(NH <sub>4</sub> ) <sub>3</sub> PO <sub>4</sub> ·3H <sub>2</sub> O, 1.04g	MgCl <sub>2</sub> ·6H <sub>2</sub> O, 0.52g CaCl <sub>2</sub> ·2H <sub>2</sub> O, 0.33g BaCl <sub>2</sub> ·2H <sub>2</sub> O, 0.62g	9	7
20	(NH <sub>4</sub> ) <sub>3</sub> PO <sub>4</sub> ·3H <sub>2</sub> O, 1.00g	MgCl <sub>2</sub> ·6H <sub>2</sub> O, 0.38g CaCl <sub>2</sub> ·2H <sub>2</sub> O, 0.24g Sr(NO <sub>3</sub> ) <sub>2</sub> , 0.39g BaCl <sub>2</sub> ·2H <sub>2</sub> O, 0.45g	9	7
21	(NH <sub>4</sub> ) <sub>3</sub> PO <sub>4</sub> ·3H <sub>2</sub> O, 0.71g	MgCl <sub>2</sub> ·6H <sub>2</sub> O, 0.53g CaCl <sub>2</sub> ·2H <sub>2</sub> O, 0.39g	9	7
Comp. Ex. 1	-	-	-	-
Comp. Ex. 2	H <sub>3</sub> PO <sub>4</sub>	-	2	3
Comp. Ex. 3	-	Ba(OC <sub>3</sub> H <sub>7</sub> ) <sub>2</sub> Ti(OC <sub>3</sub> H <sub>7</sub> ) <sub>4</sub>	-	-
Comp. Ex. 4	-	-	-	-
Comp. Ex. 5	-	-	-	-

Barium calcium magnesium phosphate	2	68	105	2100	○
Barium strontium calcium magnesium phosphate	2	69	100	2000	○
Calcium magnesium phosphate	0.9	75	100	2000	○
-		82	20	1000	x
zinc phosphate	0.7	83	22	1100	x
Barium titanate		-	-	-	x
-		115	25	1200	x
-		83	35	1300	x

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2. A phosphor as claimed in Claim 1, wherein said phosphate is selected from the group consisting of magnesium phosphate, magnesium hydrogenphosphate, barium phosphate, calcium phosphate, strontium phosphate, calcium magnesium phosphate, strontium magnesium phosphate, barium magnesium phosphate, strontium calcium magnesium phosphate, barium calcium magnesium phosphate and barium strontium calcium magnesium phosphate.

3. A phosphor as claimed in Claim 1, wherein the amount of the coating metal phosphate falls in the range satisfying the inequality;

$$0.007 \cdot \frac{d}{D_{50}} \cdot W_p \leq W_c \leq 1.5 \cdot \frac{d}{D_{50}} \cdot W_p$$

wherein  $W_c$  represents the weight of coating metal phosphate (g),  $d$  the density of coating metal phosphate ( $\text{g/cm}^3$ ),  $D_{50}$  the mean particle diameter of the phosphor and  $W_p$  the weight of phosphor (g).

4. A phosphor as claimed in Claim 1, wherein the phosphor to be coated with the phosphate is a zinc sulfide type electroluminescent phosphor.

5. A phosphor as claimed in Claim 4, wherein the mean particle diameter of the phosphor ranges from about 3 to about 60  $\mu\text{m}$ .

6. A process for producing a phosphate-coated electroluminescent phosphor for electroluminescent lamp which comprises dispersing a phosphor in an aqueous solution containing phosphate ions and alkali metal ions and/or ammonium ions, adding an aqueous solution of a salt of at least one metal selected from the group consisting of magnesium, calcium, strontium and barium to the resulting slurry while maintaining the pH value of the resulting mixture at 4 or more, coating the metal phosphate on the phosphor, then taking the phosphor from the aqueous solution by filtration, washing the coated phosphor with water and then calcining the coated phosphor.

7. A process as claimed in Claim 6, wherein said aqueous solution containing alkali metal ions and/or ammonium ions contains phosphate ions and any one of sodium ions, potassium ions and ammonium ions.

8. A process as claimed in Claim 6, wherein the mixture containing the coated phosphor is subjected to heat treatment before the filtration.

9. A process as claimed in Claim 8, wherein the temperature for the heat treatment is between 90° C and 100° C.